Improving Aerosol and Visibility Forecasting Capabilities Using Current and Future Generations of Satellite Observations

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LONG-TERM GOALS

Accurate visibility forecasts, being necessary for military operations and field applications of optically-sensitive equipment such as advanced electro-optical (EO) systems, remain as a challenging scientific problem. One reason is because large spatial and temporal variations exist, not only with aerosol physical and optical properties, but with emission sources. Clearly, to further advance aerosol forecasts and aerosol modeling studies, it is necessary to combine modeling and observational based studies through the use of space-borne observations from current and future aerosol-sensitive sensors. The long-term goal of this study is to improve the Navy's electro-optical propagation forecast capability through the use of multi-channel and multi-sensor aerosol data assimilation.

OBJECTIVES (abstract from proposal)

Critical to both military and civilian applications, the Navy Aerosol Analysis and Prediction System (NAAPS) is the only truly operational global aerosol and visibility forecasting model. Recent studies indicate that the utilization of satellite observations significantly improves NAAPS aerosol forecasting capability and reliability. To fully utilize the wide breadth and depth of various current satellite observations and to prepare for future reductions in aerosol sensing satellites over the next decade, we propose to construct a multi-channel, multi-sensor, and multi-task assimilation system to improve NAAPS forecasts for both current and future applications. The specific objectives of this study are to:

1. Finalize over-land and over-ocean aerosol assimilation methods using operational data assimilation quality Moderate Resolution Imaging Spectroradiometer (MODIS) and Multiangle Imaging SpectroRadiometer (MISR) aerosol products, and develop a framework for considering current and future satellite aerosol products.
2. Develop forward models to enable a radiance assimilation capability by: 1) improving forecast performance over cloudy regions using the Ozone Monitoring Instrument (OMI) Aerosol Index; and 2) preparing for the post-MODIS/MISR era using the Geostationary Operational Environmental Satellite (GOES).
3. Improve model representations of aerosol vertical profiles and the accuracy of aerosol speciation in NAAPS through the use of a 3-D aerosol assimilation method and a generalized Angstrom exponent assimilation scheme.

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4. Develop an improved 3-D parameterization for satellite observation and model forecasting error matrices using ground observations from the Aerosol Robotic Network (AERONET) and the Micropulse Lidar Network (MPLNET).

APPROACH

Aerosol data assimilation is a relatively new research area, as satellite remote sensing of aerosol properties itself is an ongoing research topic with potential for many improvements. For example, recent studies suggest that large discrepancies exist in even the most widely used satellite aerosol products [e.g. Shi et al., 2011]. Therefore, as the first step, discrepancies among the satellite aerosol products need to be evaluated. Then, quality assurance and empirical correction methods need to be developed for selected satellite aerosol products. In the past few years, the over land and ocean Data-Assimilation (DA) quality products from MODIS have been developed and are currently implemented for the operational aerosol forecasts at FNMOC. With the support of this project, we have also developed DA quality products for the MODIS Deepblue and MISR aerosol products. Continuing efforts will be focused on current and future sensors such as the Sea-viewing Wide Field-of-view Sensor (SeaWiFS), the Visible/Infrared Imager/Radiometer Suite (VIIRS), and GOES.

With the support from ONR, the Naval Research Laboratory (NRL) Atmospheric Variational Data Assimilation System (NAVDAS) Aerosol Optical Depth (NAVDAS-AOD) system has been developed and is currently running operationally at FNMOC. NAVDAS-AOD is used as a baseline for assimilating column integrated aerosol optical depth and fine mode fraction data from satellite aerosol products such as MODIS and MISR into the NAAPS model. Several steps have been or are being taken to improve upon the NAVDAS-AOD baseline method. First, to enhance the vertical representation of aerosol plumes in NAAPS, a 3-D aerosol assimilation scheme has been developed for assimilating aerosol vertical profiles from the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) [Zhang et al., 2011]. Second, continuing efforts show the potential benefits of using OMI data for improving aerosol forecast accuracy over cloudy regions, and incorporating these data will be attempted using the OMI aerosol index above cloud decks through a radiance assimilation method. Third, we have to prepare for the era when most aerosol-sensitive, research grade sensors will be decommissioned and only base satellite observations such as GOES will be available. Therefore, as a backup plan to operational aerosol forecasts, a scheme that assimilates GOES radiance data needs to be developed. Currently, a forward model for GOES radiance assimilation is under construction using the Community Radiative Transfer Model *(*CRTM).

New research questions and issues arise as we approach these research tasks. The significance of new questions cannot be underestimated as historically they are the sources of some major scientific discoveries. In this research project, we have identified that nighttime aerosol retrievals, although not included in the original proposal, are needed for reducing uncertainties in nighttime aerosol forecasts [e.g. Zhang et al., 2011]. Therefore, a nighttime aerosol study is currently being conducted with the use of data from VIIRS. Additionally, a controversial belt of high aerosol optical depth was identified from some of the satellite aerosol products over the mid- to high-latitudes in the southern hemisphere. The community has conflicting opinions regarding this phenomenon, as some studies credit it to natural causes while others credit it to artificial features. As part of the past year's research effort, we have also studied this phenomenon. This study gave us a better understanding of the uncertainties in satellite aerosol products. Lastly, with the use of DA quality satellite aerosol products, we have also studied aerosol trends for the past decade. This study is planned to be included in the next release of the IPCC report.

WORK COMPLETED

Successful progress has been made in all three of the targeted approaches, including satellite aerosol products analysis, new aerosol assimilation scheme development, and new and unexpected research discoveries (collaborating with NRL scientists Dr. Jeff Reid, Dr. Edward Hyer, Dr. James Campbell, and Dr. Douglas Westphal). A total of 9 author/coauthor journal papers are published/in press/submitted and 10 conference presentations have been given from the University of North Dakota research group supported by this grant.

New discoveries: One of the issues in the current aerosol modeling efforts, as identified from our study, is the lack of nighttime aerosol operations. The recently launched VIIRS instrument onboard the Suomi National Polar-orbiting Partnership (NPP) satellite includes a Day/Night Band (DNB) sensor that improves upon the Operational Linescan System (OLS) design. Using VIIRS DNB observations, we have developed new methods for detecting and retrieving the properties of nighttime aerosol using data from regions with and without artificial light emissions. A journal paper has been submitted on this issue.

One unique example of potential signal bias has been found from aerosol optical depth (AOD) datasets collected by some passive satellite instruments over the mid- to high-latitude Southern Oceans (defined from 45° S to 65° S). An intermittent band of relatively high AOD is found with MODIS, MISR and the Global Aerosol Climatology Project (GACP) datasets, yet this band is not reported by some of the other aerosol products such as SeaWiFS and CALIOP. Clearly, discrepancies in optical property retrievals exist over the high latitude Southern Oceans between many of the most prominent aerosol datasets used by the community. The domain encompassing these discrepancies is not of trivial size, and thus, attempts to climatologically depict significant aerosol presence in regional and global climate models can be affected by significant error introduced within radiative and circulatory dynamic processes [e.g., Koffi et al., 2012]. We investigated co-located aerosol optical depth retrievals from MODIS, CALIOP, Maritime Aerosol Network (MAN), and AERONET datasets over the mid- to high-latitude Southern Oceans for the occurrence of elevated and likely biased values, referred to as the Elevated Southern Oceans Anomaly (ESOA). A journal paper is in preparation for submission in the near future.

We have updated our 2000-2009 MODIS and MISR aerosol trend analysis to 2000-2012. New approaches were developed to account for calibration drifts in the MODIS aerosol products. This study is scheduled to be included in the next version of the IPCC report.

Improvements to aerosol data assimilation schemes: With the use of the recently developed 2D/3DVar NAVDAS-AOD aerosol assimilation package, we have evaluated the performance of multi-sensor data assimilation using MODIS, MODIS Deepblue, MISR, and CALIOP data. Data denial methods were used to study the regional and global impacts of each product on the performance of NAAPS aerosol analyses and forecasts. A conference presentation was given at the 2011 AGU Fall Meeting and a journal paper from this study is being prepared.

Improvements were also made to downscale the NAVDAS-AOD to a finer spatial scale. The original spatial resolution for NAVDAS-AOD is 1°×1° (Latitude/Longitude). To meet the increasing requirements for the finer scale aerosol analysis and forecasts, we have developed a new version of NAVDAS-AOD with 0.5°×0.5° (Latitude/Longitude) spatial resolution. Currently, we are working on

developing an updated system with the spatial resolution increased to 0.3°×0.3° for advanced applications such as air pollution.

A new system has been constructed coupling the Fu-Liou radiative transfer model with NAAPS forecast and analysis fields to estimate short-wave (SW) and long-wave (LW) flux energy as well as atmospheric heating profiles. This system will facilitate applications of NAAPS output data for climate studies and introduce the possibility of using broadband data for improving aerosol forecasts. This study is currently being used to investigate the impacts of CALIOP data assimilation on the atmospheric energy balance and aerosol climate forcing.

Satellite aerosol data product analysis: Continuing with the previous year's efforts, we have finished developing the DA quality MODIS DeepBlue product. Our study indicates that the DeepBlue product could improve model performance over North Africa where the commonly used MODIS aerosol products do not have valid retrievals. The version 6 (v6) MODIS DeepBlue aerosol product is scheduled to be released next year. By collaborating with scientists from NASA GSFC, we have also investigated the performance of the algorithms developed for the version 5.1 MODIS DeepBlue aerosol product using two months of v6 MODIS DeepBlue data. Research is currently progressing for the development of DA quality MISR products. We have also initiated a study for evaluating the SeaWiFS aerosol products. One journal paper has been submitted and one journal paper is in preparation regarding this research subject.

AERONET station: The local AERONET station was constructed and is currently in operation. The data collected from the Grand Forks AERONET site have already been used in the nighttime study of this project.

RESULTS

Toward Nighttime Aerosol Optical Depth Retrievals from the VIIRS Day/Night Band (Johnson et al., 2012, submitted)
A great need exists for reliable nighttime aerosol products at high spatial and temporal resolution. Using VIIRS Day/Night Band (DNB) observations on the NPP satellite, a new method is proposed for retrieving nighttime aerosol optical depth (AOD) using the contrast between regions with and without artificial lights. Associated with this method is a VIIRS aerosol optical depth index (VAODI) for detecting the presence of aerosol plumes. Evaluation of the retrieved AOD values against daytime AERONET data from before and after the overpass of the VIIRS satellite over the Cape Verde and Grand Forks AERONET stations yields a correlation of 0.8. A high correlation (0.93) between the VAODI and the AERONET data was also found (Figure 1). This study suggests that the VIIRS DNB has great potential for providing useful nighttime aerosol detection and retrievals.

Investigating Elevated Aqua MODIS Aerosol Optical Depth Retrievals over the Mid-Latitude Southern Oceans through Intercomparison with Co-Located CALIOP, MAN, and AERONET Datasets (Toth et al., 2012, in preparation for submission in the near future)
A band of elevated aerosol optical depths (AOD) over the mid- to high-latitude Southern Oceans have been identified in some passive satellite-based aerosol datasets, including most prominently from MODIS and MISR products. Some in the field contend much of this signal is artifactual, while others believe it is largely physical. In this paper, Aqua MODIS aerosol products in this zonal region are investigated to assess retrieval accuracy. This is done through multiple data sets, including spatially and temporally collocated with cloud and aerosol products produced by the CALIOP project for

investigating Aqua MODIS AOD in this region with respect to lidar profiling of cloud presence. Maritime Aerosol Network (MAN) and Aerosol Robotic Network (AERONET) AOD data are also collocated with Aqua MODIS for surface context. The results of this study suggest that the apparent high AOD belt, seen in some satellite aerosol products based on passive remote sensing methods, is not seen in the CALIOP aerosol product based on an active remote sensing technique with an enhanced cloud detection capability and is not detected from ground-based observations such as MAN and AERONET data. The apparent high AOD belt, although mostly contributed to stratocumulus and low broken cumulus cloud contamination as suggested by CALIOP products, could not be fully credited to cloud contamination. Collocated CALIOP data also suggest that the current cloud screening methods implemented in the over ocean Aqua MODIS aerosol products are ineffective in identifying cirrus clouds. Cloud residuals still exist in the Aqua MODIS AOD products even with the use of the most stringent cloud screening setting. These Aqua MODIS aerosol product cloud residuals could represent a high global AOD bias of 0.03 if all valid Aqua MODIS retrievals are used and a high bias of 0.005 even if the most stringent cloud screening setting is applied.

The impact of multi-sensor satellite aerosol products on aerosol data assimilation in the NAAPS model (Johnson et al., 2011, AGU)
With recent advancements in satellite aerosol technology, such as high spatial and spectral resolution measurements from multi-sensor, multi-channel, multi-angle, and polarized satellite platforms, the aerosol modeling community has started tapping into these observations to improve the accuracy of model forecasts. Remaining to be addressed is the identification of the benefits each of these sensors has on model performance and the determination of the ability of current observational platforms to provide adequate amounts of data for aerosol data assimilation. To allay these concerns a series of analyses and forecasts are evaluated. These analyses and forecasts are prepared with a 2D/3DVAR aerosol assimilation scheme that uses various combinations of satellite aerosol products and the NAAPS model. The satellite aerosol products that are used come from the MODIS, the MISR, and the CALIOP instruments. The performance of NAAPS is evaluated with three methods: an own-analysis where model forecasts are compared to analyses at the same valid time, a comparison to AErosol RObotic NETwork (AERONET) data for point validation, and a comparison to MODIS and MISR retrievals. The improved performance of the NAAPS model is monitored with each instrument that is added to the data assimilation process, from a natural run with no assimilated observations, to 2DVAR with MODIS, then MISR, and then Deep Blue observations, to coupled 2D/3DVAR with the addition of CALIOP observations. Forecast errors are also studied with respect to forecast length and the spatial and temporal distribution of observations. Subsequently, the need for new types of aerosol retrievals and measurements are discussed.

Critical evaluation of MODIS Deep Blue aerosol optical depth product for data assimilation over North Africa (Shi et al., 2012, submitted)
A total of eight years of Terra (2000-2007) and Aqua (2002-2009) Moderate Resolution Imaging Spectroradiometer (MODIS) Deep Blue (DB) collection 5.1 (c5.1) data were examined for their potential usage in aerosol assimilation. Uncertainties in the DB Aerosol Optical Depth (AOD) were identified and studied. Empirical corrections and quality assurance procedures were developed for North Africa and the Arabian Peninsula. After applying quality assurance and quality check procedures, the Root-Mean-Square-Error (RMSE) in the MODIS Terra and Aqua AOD are reduced by 18.1% and 18.2% to 0.16 and 0.17, respectively, with respect to AERONET data. These procedures were also applied to two months of DB collection 6 (c6) AOD data, and reductions in RMSE were found, indicating that the algorithms developed for c5.1 data are applicable to c6 data to some extent.

A new quality-assured DB level 3 AOD product was developed for future implementations in both aerosol data assimilation and climate related applications.

Developing a coupled system for applying Fu-Liou radiative transfer model/parameterizations to NAAPS analyses (Figure 2).

A coupled NAAPS and Fu-Liou system was developed. This system applies Fu-Liou calculations within NAAPS, which allows us to simultaneously isolate direct shortwave (SW) and longwave (LW) aerosol radiative properties either for a single field or for regional/seasonal properties over many successive runs. NAAPS aerosol and meteorological fields, the International Geosphere-Biosphere Programme *(*IGBP) SW and LW surface characteristics, and an ozone climatology are used as inputs for the Fu-Liou radiative transfer calculations. The NAAPS Fu-Liou system is depicted in part in Fig. 2. In Fig. 2, the monthly mean (June 2007) differences are shown between daytime TOA LW fluxes for the 2DVAR analysis and the coupled 2D/3DVAR system that additionally assimilates CALIOP. The primary impact of CALIOP assimilation on the model is the redistribution of mass toward the boundary layer from the free troposphere. For high aerosol particle incident regions, like the Sahara and southern Asia, a warmer aerosol layer is derived. These data represent fundamentally sounder depictions of aerosol particle structure over these key production/transport regions.

Reducing spatial resolution for NAVDAS-AOD (Figure 3)

A finer spatial resolution in aerosol forecasts is needed for various applications including air quality studies. The current version of NAVDAS-AOD is 1°×1° (Latitude/Longitude). We have developed 0.5° MODIS over land and over ocean quality assured data-assimilation ready products through joint collaboration with Dr. Edward Hyer from NRL. A 0.5° x 0.5° resolution aerosol assimilation model has been developed for improving NAAPS data using the 0.5° MODIS aerosol retrievals. Figure 3 shows the comparison between a 1° and 0.5° NAAPS analysis with 2DVAR assimilation using both 1° and 0.5° NAVDAS-AOD and NAAPS, respectively. Although general patterns are similar, differences can be observed for finer scale features. As an ongoing research effort, a finer resolution 0.3° NAVDAS-AOD is also under construction.

IMPACT/APPLICATIONS

Nighttime aerosol studies are important to both civilian and military applications. For example, operations that commence at daybreak are particularly sensitive to data timeliness, while typical daytime satellite observations of large aerosol events are often received too late to provide useful guidance. The nighttime aerosol plume detection and optical property retrieval, however, are not well studied. Using VIIRS data from the recently launched NPP satellite, we have developed retrieval methods and demonstrated the potential of studying the presence of nighttime aerosol plumes and their physical properties using city lights.

TRANSITIONS

The latest version of the NAAPS Fu-Liou system has been transitioned to NRL for further evaluation.

RELATED PROJECTS

The nighttime study is also partially supported by the University of North Dakota Faculty Seed Money project. Graduate student Yingxi Shi is supported by the NASA Earth and Space Science Fellowship Program.

REFERENCES

Koffi, B., et al., Application of the CALIOP layer product to evaluate the vertical distribution of aerosols estimated by global models: AeroCom phase I results, J. Geophys. Res., 117, D10201, doi:10.1029/2011JD016858, 2012.

Johnson R. S., J. Zhang, J. S. Reid, E. J. Hyer, and S. D. Miller, Toward Nighttime Aerosol Optical Depth Retrievals from the VIIRS Day/Night Band, submitted to GRL, 2012.

Johnson R. S., J. Zhang, J. S. Reid, E. J. Hyer, J. R. Campbell, D. L. Westphal, W. Sessions, The impact of multi-sensor satellite aerosol products on aerosol data assimilation in the NAAPS model*,* Abstract A53C-0357 presented at 2011 Fall Meeting, AGU, San Francisco, Calif., 5-9 Dec, 2011.

Shi Y., J. Zhang, J. S. Reid, E. Hyer, and N. C. Hsu, Critical evaluation of MODIS Deep Blue aerosol optical depth product for data assimilation over North Africa, submitted to AMT, 2012.

Shi Y., Zhang J., Reid J. S., Hyer E. J., Eck T. F., and Holben B. N., A critical examination of spatial biases between MODIS and MISR aerosol products – application for potential AERONET deployment, Atmos. Meas. Tech., 4, 2823–2836, 2011.

Toth T. D., J. Zhang, J. R. Campbell, J. S. Reid, Y. Shi, R. S. Johnson, A. Smirnov, M. A. Vaughan and D. M. Winker, Investigating Elevated Aqua MODIS Aerosol Optical Depth Retrievals over the Mid-Latitude Southern Oceans through Intercomparison with Co-Located CALIOP, MAN, and AERONET Datasets, In preparation for submission to JGR, 2012.

Zhang, J., J. R. Campbell, J. S. Reid, D. L. Westphal, N. L. Baker, W. F. Campbell, and E. J. Hyer, Evaluating the impact of assimilating CALIOP-derived aerosol extinction profiles on a global mass transport model, Geophys. Res. Lett., 38, L14801, doi:10.1029/2011GL047737, 2011.

PUBLICATIONS

Johnson R. S., J. Zhang, J. S. Reid, E. J. Hyer, and S. D. Miller, Toward Nighttime Aerosol Optical Depth Retrievals from the VIIRS Day/Night Band, submitted to GRL, 2012 [submitted, refereed].

Shi Y., J. Zhang, J. S. Reid, E. Hyer, and N. C. Hsu, Critical evaluation of MODIS Deep Blue aerosol optical depth product for data assimilation over North Africa, submitted to AMT, 2012 [submitted, refereed].

Sayer, A. M., N. C. Hsu, C. Bettenhausen, Z. Ahmad, B. N. Holben, A. Smirnov, G. E. Thomas, and *J. Zhang* , SeaWiFS Ocean Aerosol Retrieval (SOAR): Algorithm, validation, and comparison with other data sets, J. Geophys. Res., 117, D03206, doi:10.1029/2011JD016599, 2012 [published, refereed].

Yu, H., Zhang. Y., Chin M., Liu Z., Omar A., Remer L. A. Yang Y., Yuan T. and *Zhang J.* An Intergrated Analysis of Aerosol above Clouds from A-Train Multi-sensor Measurements, 121, 125–131, 2012 [published, refereed].

Campbell J.R., J. L. Tackett, J. S. Reid, *J. Zhang*, C. A. Curtis, E. J. Hyer, W. R. Sessions, D. L.Westphal, J. M. Prospero, E. J. Welton, A. H. Omar, M. A. Vaughan, and D. M.Winker, Evaluating nighttime CALIOP 0.532μm aerosol optical depth and extinction coefficient retrievals, Atmos. Meas. Tech., 5, 2143–2160, doi:10.5194/amt-5-2143-2012, 2012 [published, refereed].

Sayer, A. M., Hsu, N. C., Bettenhausen, C., Jeong, M.-J., Holben, B. N., and *Zhang, J.*: Global and regional evaluation of over-land spectral aerosol optical depth retrievals from SeaWiFS, Atmos. Meas. Tech. Discuss., 5, 2169-2220, doi:10.5194/amtd-5-2169-2012, 2012 [published, refereed].

Reid J., E. J. Hyer, *R. Johnson*, B. N. Holben, *J. Zhang*, J. R. Campbell, S. A. Christopher, L. Di Girolamo, L. Giglio, R. E. Holz, C. Kearney, J. Miettinen, E. A. Reid, F. J. Turk, J. Wang, P. Xian, R. J. Yokelson, G. Zhao, R. Balasubramanian, B. N. Chew, S. Janai[1], N. Lagrosas, P. Lestari, N. Lin, M. Mahmud, B. Norris, A. X. Nguyen, N. T. K. Oahn, M. Oo, S. Salinas, and S. C. Liew, Observing the Southeast Asian aerosol system by remote sensing: A critical review for the Seven Southeast Asian Studies (7SEAS) program, *Atmospheric Research*, In Press, 2012 [in press, refereed].

Campbell J.R., J. S. Reid, D. L. Westphal, *J. Zhang*, B. N. Chew, E. J. Welton, A. Shimizu and N. Sugimoto, Characterizing Aerosol Particle Composition and the Vertical Profile of Extinction and LinearDepolarization over Southeast Asia and the Maritime Continent: The 2007-2009 View from CALIOP, *Atmospheric Research*, In Press, 2012 [in press, refereed].

Xian, P., J.S. Reid, S.A. Atwood, *R.S. Johnson*, E.J. Hyer, D.L. Westphal, W. Sessions, Smoke aerosol transport patterns over the maritime continent, *Atmos. Res*., 2012 [in press, refereed].

T.D. Toth, J. Zhang, J.R. Campbell, J.S. Reid, *Yingxi Shi, R.S. Johnson*, Alexander Smirnov, and M.A. Vaughan, An Intercomparison of MODIS, CALIOP, and MAN to Investigate Elevated Passive Satellite Marine Aerosol Optical Depth Retrievals over the Mid-Latitude Southern Oceans, Sea Spray Aerosol Workshop, Raleigh, NC, June, 2012.

Zhang J., J. S. Reid, J. R. Campbell, E. J. Hyer, D. L. Westphal, *Y. Shi, R. S. Johnson*, and N. L. Baker, Development of a Multi-Sensor Aerosol Data Assimilation Method From MODIS, MISR, and CALIPSO Aerosol Products for Operational and Climate Applications, 18th Conference on Satellite Meteorology, Oceanography and Climatology/ First Joint AMS-Asia Satellite Meteorology Conference, New Orleans, 22-26, January, 2012.

Toth T. D., Y. Shi, J. Zhang, J. R. Campbell, and J. S. Reid, A Satellite Analysis of Aerosol and Cloud Properties Over the Southern Midlatitude Oceans, Fourth Symposium on Aerosol-Cloud-Climate Interactions, New Orleans, 22-26, January, 2012.

Johnson R. S., J. Zhang, J. S. Reid, E. J. Hyer, J. R. Campbell, D. L. Westphal, W. Sessions, The impact of multi-sensor satellite aerosol products on aerosol data assimilation in the NAAPS model, Abstract A53C-0357 presented at 2011 Fall Meeting, AGU, San Francisco, Calif., 5-9 Dec, 2011.

Shi, Y., J. Zhang, J. S. Reid, *B. Liu, R. Deshmukh*, Multi-sensor Analysis on Data-Assimilation-Quality MISR Aerosol Products, Abstract A53C-0358 presented at 2011 Fall Meeting, AGU, San Francisco, Calif., 5-9 Dec, 2011.

T. D. Toth, Y. Shi, J. Zhang, J. R. Campbell, J. S. Reid, A Multi-Sensor Analysis of Satellite Aerosol Optical Depth Retrievals Over the Southern Oceans, Abstract A53C-0363 presented at 2011 Fall Meeting, AGU, San Francisco, Calif., 5-9 Dec, 2011.

James R. Campbell, *J. Zhang*, Jeffrey S. Reid, Douglas L. Westphal, Walter R. Sessions, Angela Benedetti, Ellsworth J. Welton, Aerosol Lidar Profiling and Data Assimilation for Operational Global Mass transport Modeling and Visibility Forecasting, 26^{th} International *L*aser Radar Conference, Porto Heli, Greece, June, 2012.

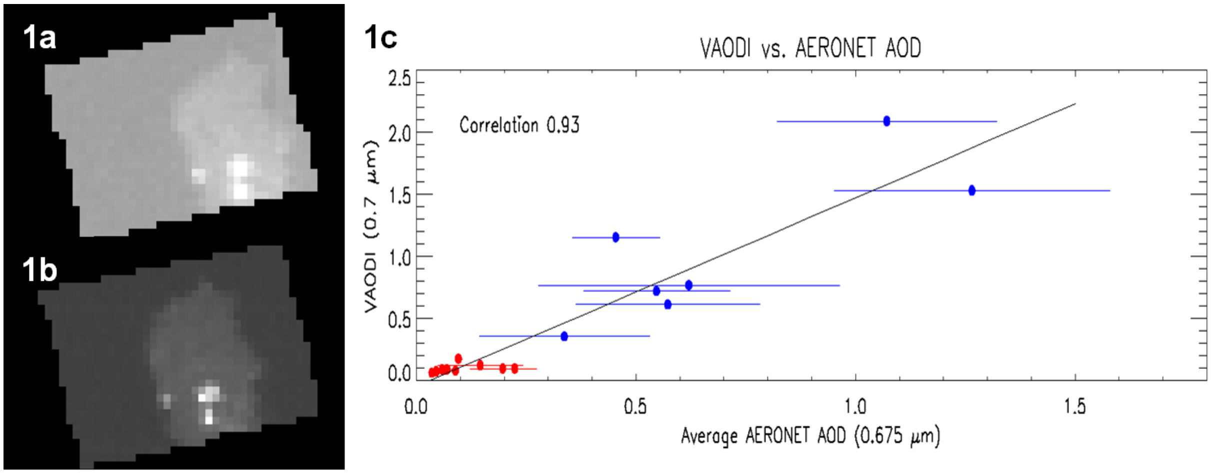
Reid J., *R. S. Johnson*, E. Hyer, *J. Zhang*, J. R. Campbell, S. A. Christopher, L. Di Girolamo, L. Giglio, J. P. Hoffman, B. Holben, R. Holz, A. P. Kuciauskas, S. C. Liew, J. Miettinen, F. J. Turk, J. Wang, E. J. Welton, and P. Xian, Observing and Understanding the Southeast Asian Aerosol Environment: A Survey of Remote Sensing Tools for the 7 Southeast Asian Studies (7SEAS) Program (invited), 18th Conference on Satellite Meteorology, Oceanography and Climatology/ First Joint AMS-Asia Satellite Meteorology Conference, New Orleans, 22-26, January, 2012.

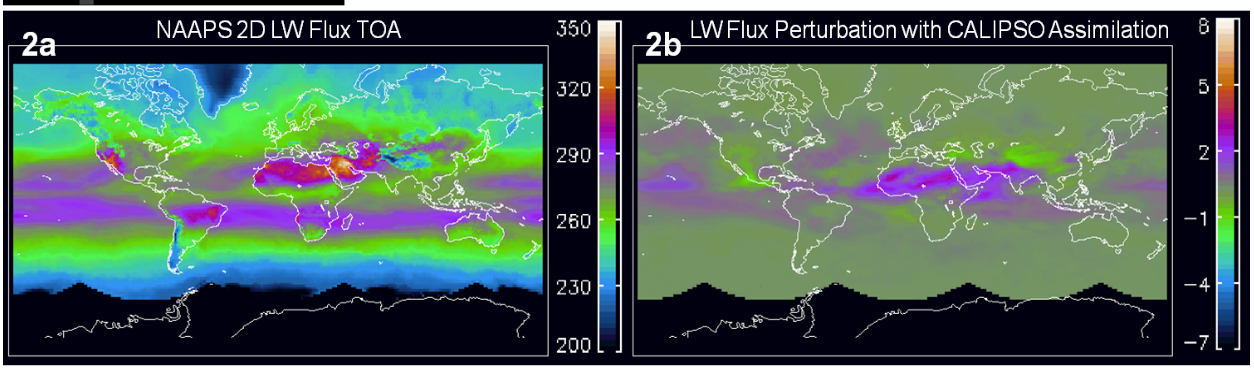
Reid, J. S., J. R. Campbell, L. Di Girolamo, D. Hegg, E. J. Hyer, W. C. Keene, A. Smirnov, T. D. Toth, A. van Eijk; J. Zhang, A Critical Examination of Aerosol Observability in the Clean Marine Environment *(Invited),* Abstract A24A-01 presented at 2011 Fall Meeting, AGU, San Francisco, Calif., 5-9 Dec, 2011.

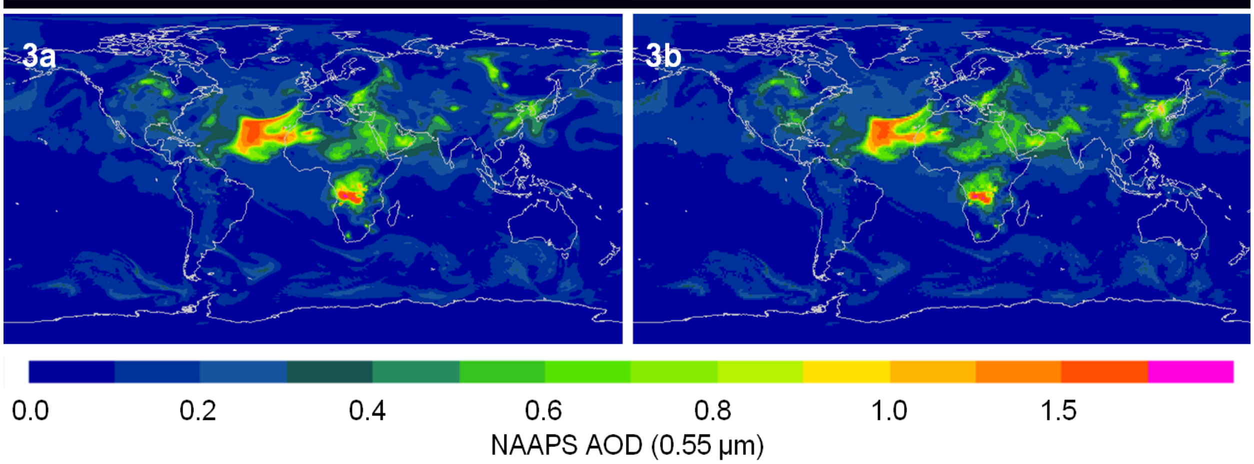
Campbell, J. R., J. L. Tackett, J. S. Reid, *J. Zhang*, D. L. Westphal, M. Vaughan, D. M. Winker, E. J. Welton, J. M. Prospero, A. Shimizu, N. Sugimoto, Evaluating CALIOP Nighttime Level 2 Aerosol Profile Retrievals Using a Global Transport Model Equipped with Two-Dimensional Variational Data Assimilation and Ground-Based Lidar Measurements, Abstract A52D-04, presented at 2011 Fall Meeting, AGU, San Francisco, Calif., 5-9 Dec, 2011.

HONORS/AWARDS/PRIZES

Dr. Jianglong Zhang from University of North Dakota is the recipient of the 2011 NOAA David Johnson award.







1a.) Nighttime imagery of Cape Verde on Sal Island on the night of February 8, 2012. 1b.) Same as 1a, except for the night of February 9, 2012 when the aerosol loading is much lower. 1c.) VIIRS Aerosol Optical Depth Index plotted against average AOD values taken from before and after the VIIRS satellite overpass.

2a.) Monthly (June 2007) mean daytime long wave flux using NAAPS analyses with only 2DVAR assimilation. 2b.) Monthly (June 2007) mean difference in daytime long wave flux calculated using NAAPS 2DVAR and 2D/3DVAR analyses.

3a.) NAAPS analysis for July 31, 2007 at 18 UTC using the 0.5° NAAPS model and NAVDAS-AOD with over land MODIS data assimilated. 3b.) Same as 3a, except for using the 1° NAAPS model and NAVDAS-AOD.